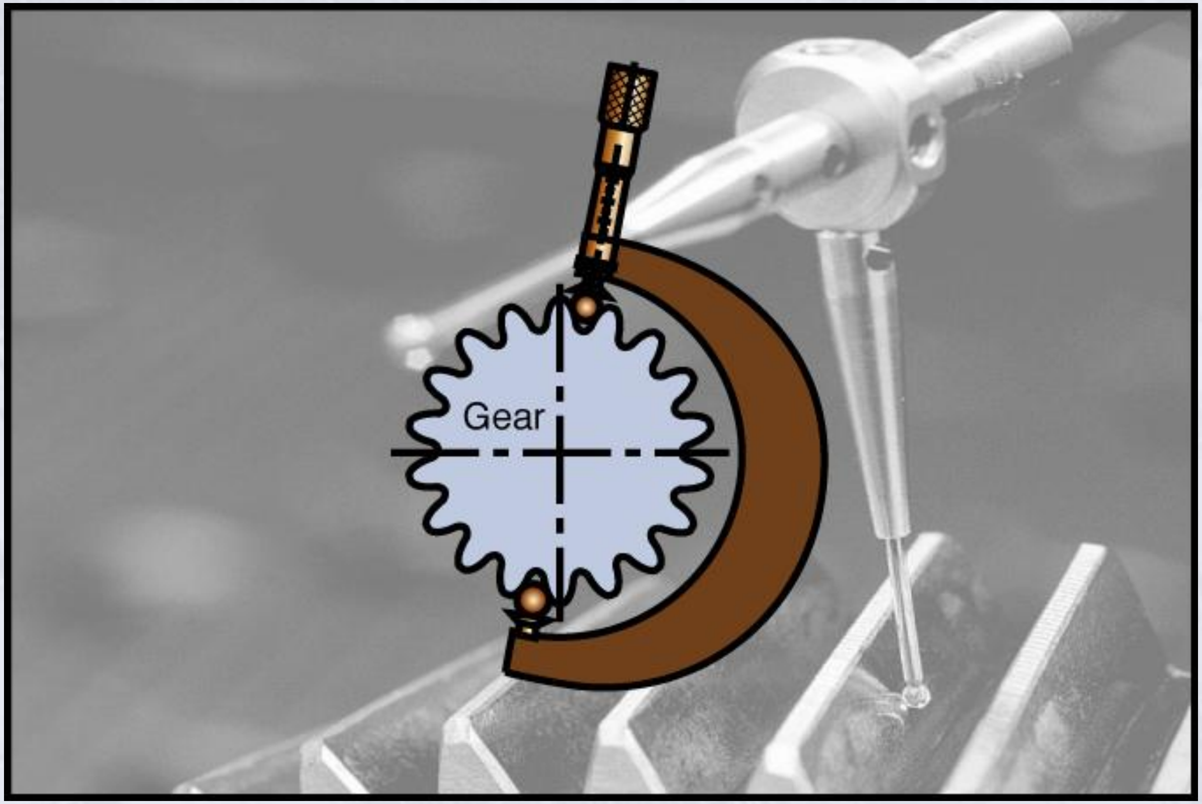
Engineering Metrology and Instrumentation



Machine-Tool Slideway

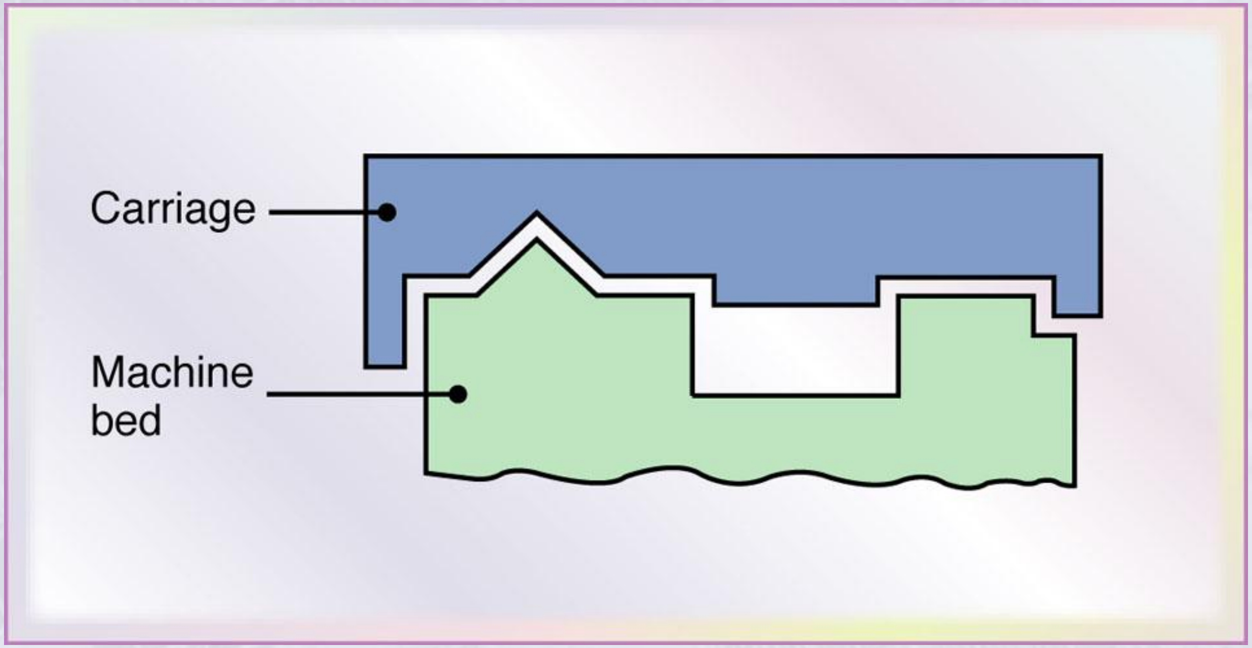
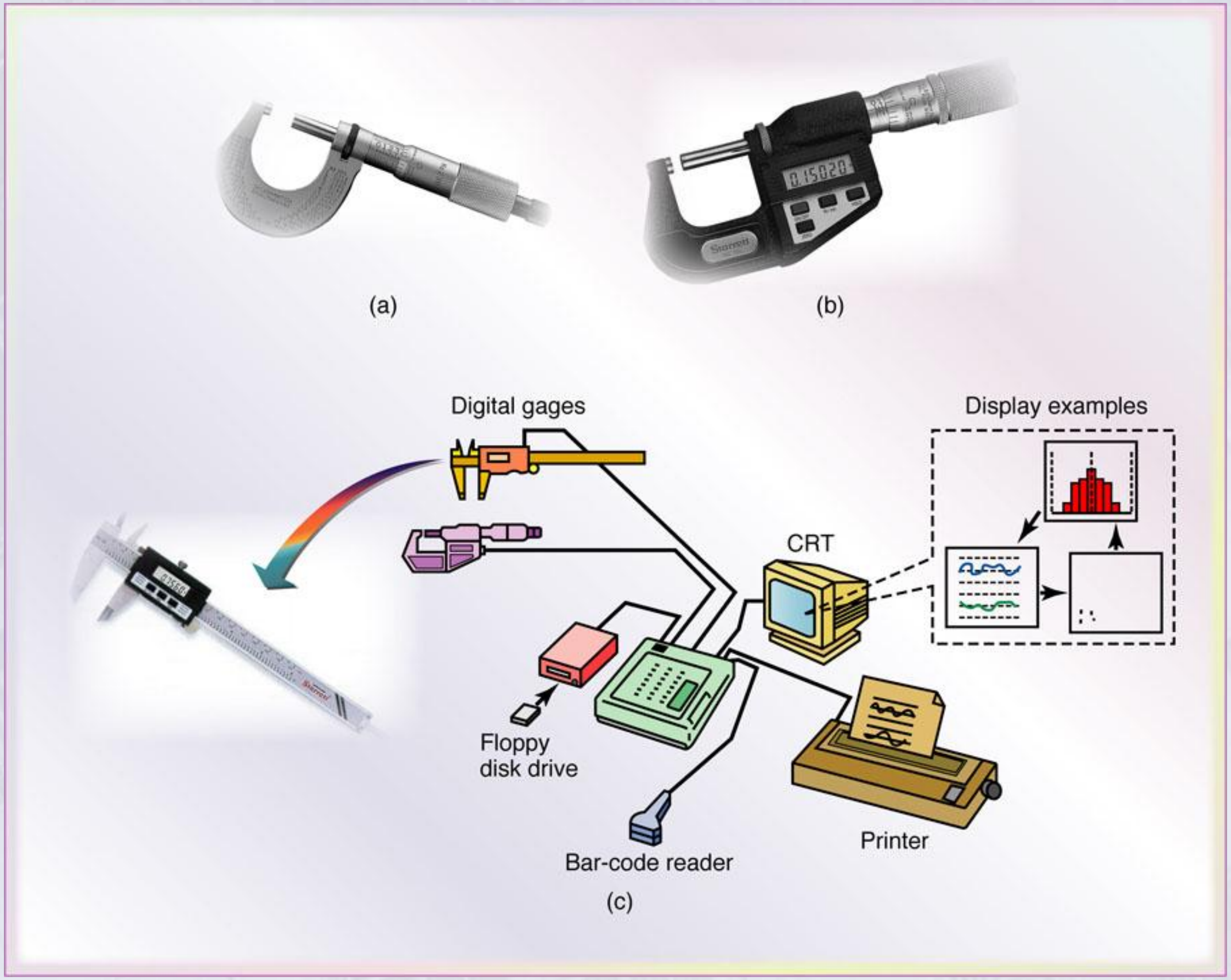


Figure 35.1 Cross-section of a machine-tool slideway. The width, depth. Angles, and other dimensions all must be produced amd measured accurately for the machine tool to function as expected.



Analog and Digital Measuring Devices

Figure 35.2 (a) A vernier (analog) micrometer. (b) A digital micrometer with a range of 0 to 1 in. (0 to 25 mm) and a resolution of 50 μin. (1.25μm). It is generally easier to read dimensions on this instrument compared to the analog micrometer. (c) Schematic illustration showing the integration of digital gages with microprocessors for real-time data acquisition for statistical process control. *Source*: (a) Courtesy of L.C. Starret Co. and (b) Courtesy of Mitutoyo Corp.

Digital-Micrometer Depth Gage

Figure 35.3 A digital micrometer depth gage.
Source: Courtesy of Starret Co.

Dial Indicator Uses

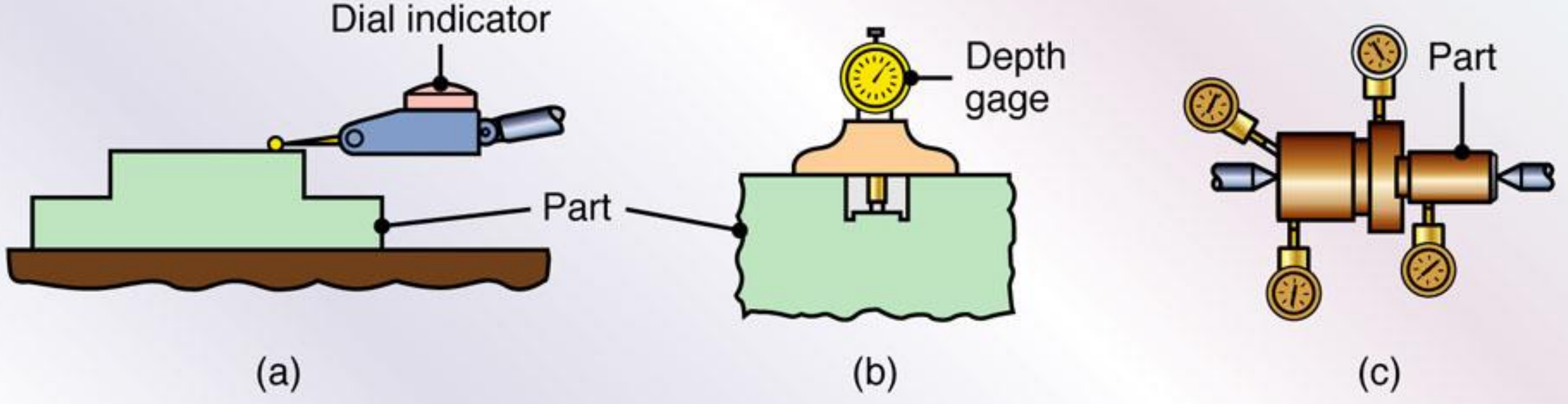


Figure 35.4 Three uses of dial indicators: (a) roundess, (b) depth, and (c) multiple-dimension gaging of a part.

Measuring Straightness

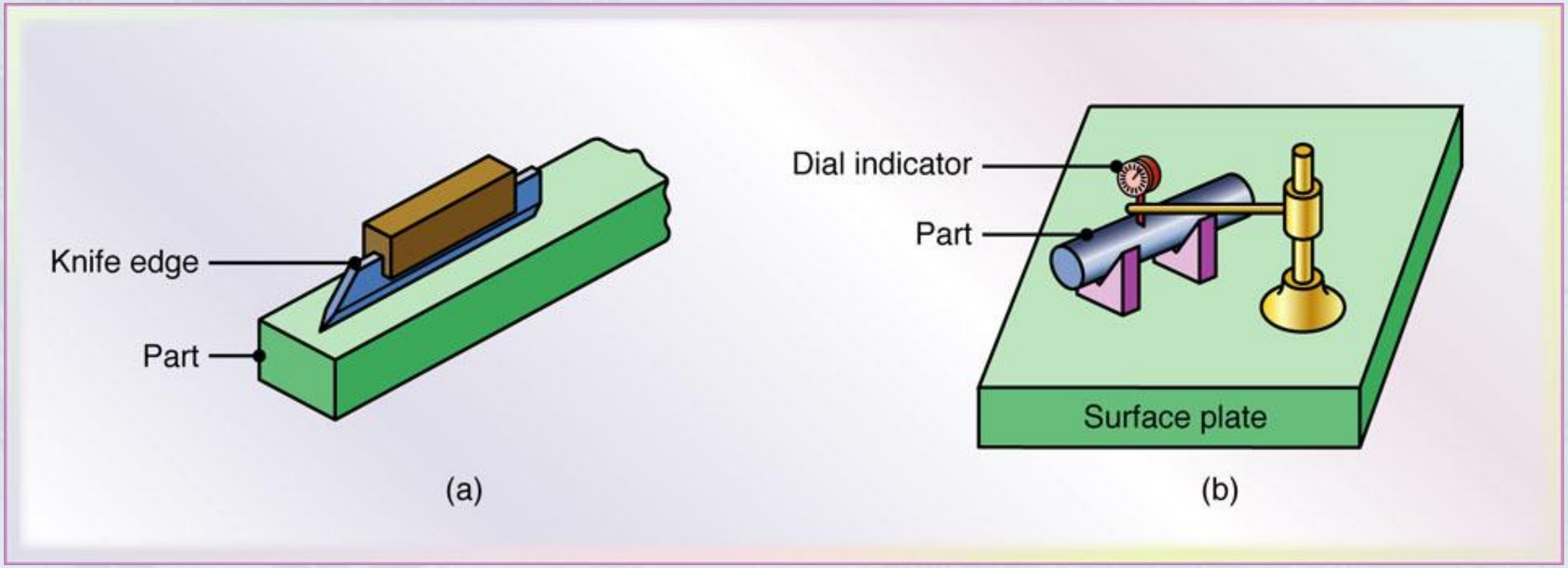


Figure 35.5 Measuring straightness manually with (a) a knife-edge rule and (b) a dial indicator. *Source*: After F. T. Farago.

Measuring Flatness

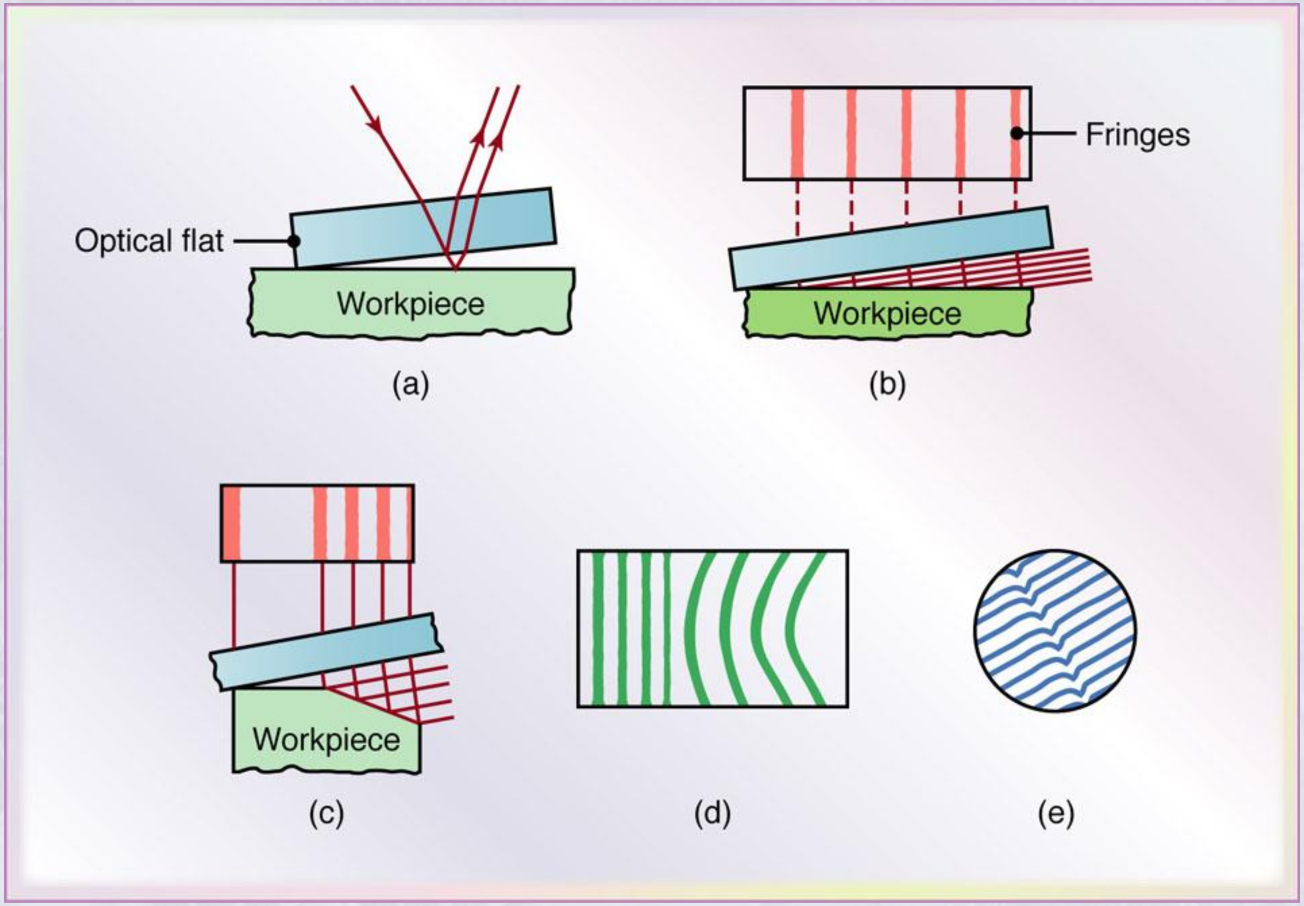


Figure 35.6 (a) Interferometry method for measuring flatness using an optical flat. (b) Fringes on a flat, inclined surface. An optical flat resting on a perfectly flat workpiece surface will not split the light beam, and no fringes will be present. (c) Fringes on a surface with two inclinations. *Note*: the greater the incline, the closer together are the fringes. (d) Curved fringe patterns indicate curvatures on the workpiece surface.

Measuring Roundness

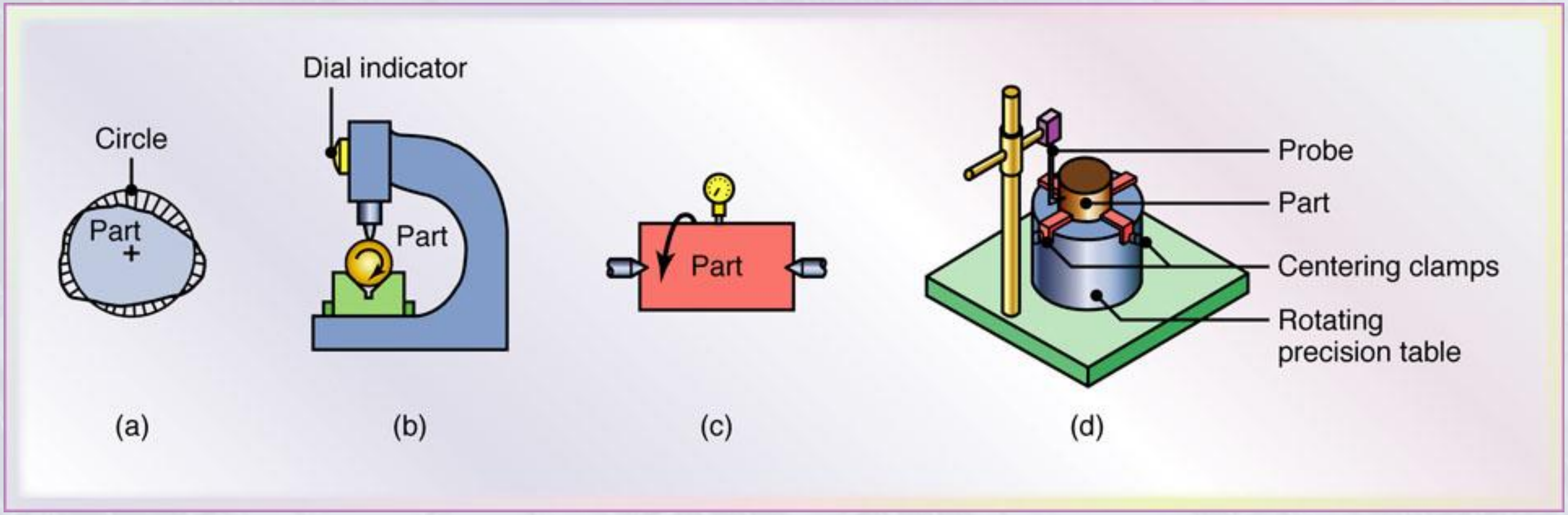


Figure 35.7 (a) Schematic illustration of out-of-roundess (exaggerated). Measuring roundess using (b) a V-block and dial indicator, (c) a round part supported on centers and rotated, and (d) circular tracing. *Source*: After F. T. Farago.

Measuring Gear-Tooth Thickness and Profile

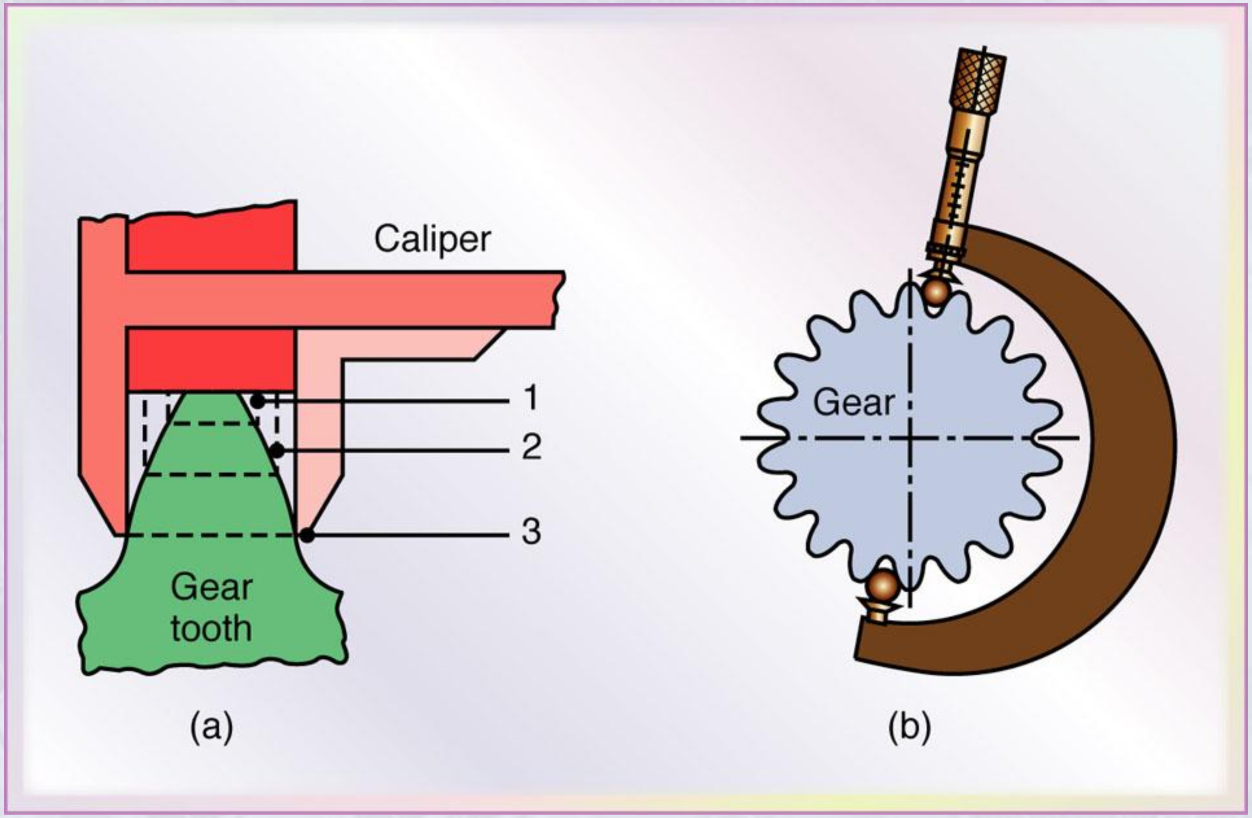


Figure 35.8 Measuring gear-tooth thickness and profile with (a) a gear-tooth caliper and (b) pins or balls and a micrometer. *Source:* Courtesy of American Gear Manufacturers Association.

Optical Contour Projector

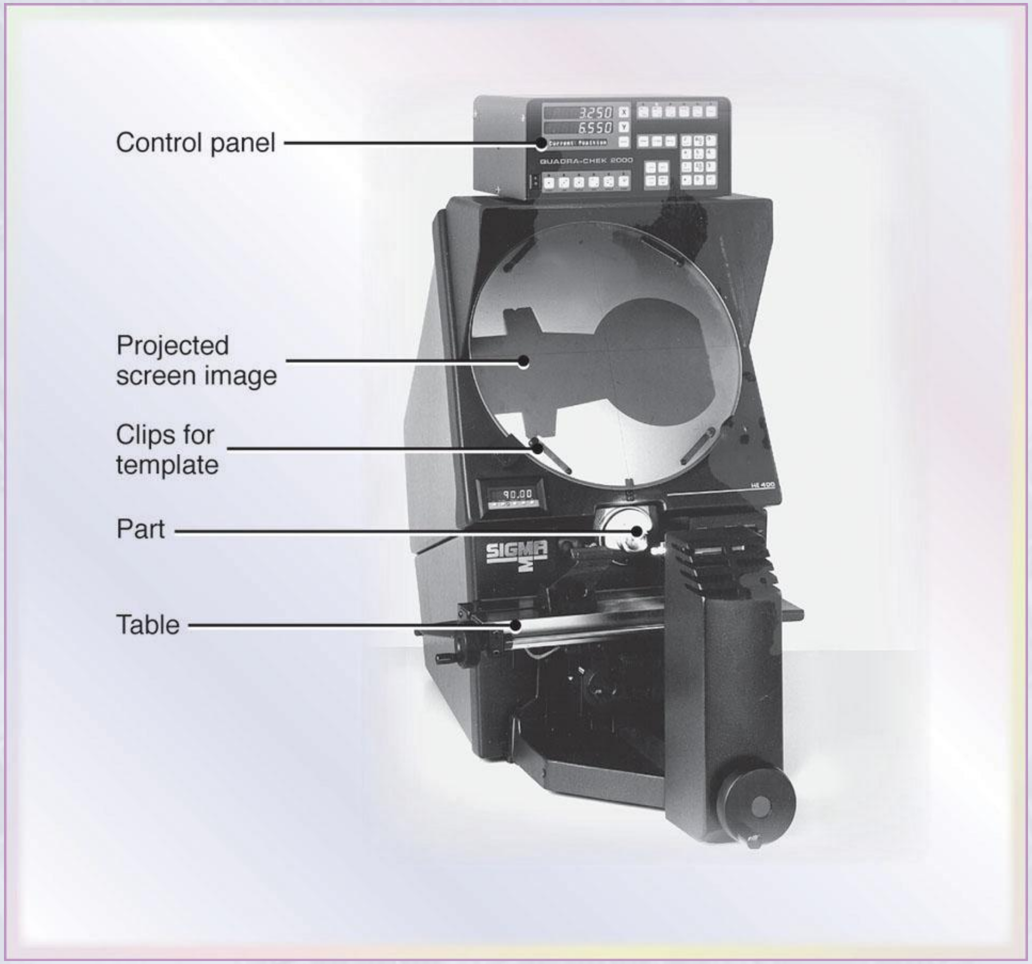


Figure 35.9 A bench-model horizontal-beam contour projector with a 16-in. diameter screen with 150-W tungsten halogen illumination. *Source*: Courtesy of L. S. Starrett Company, Precision Optical Division.

Fixed Gages

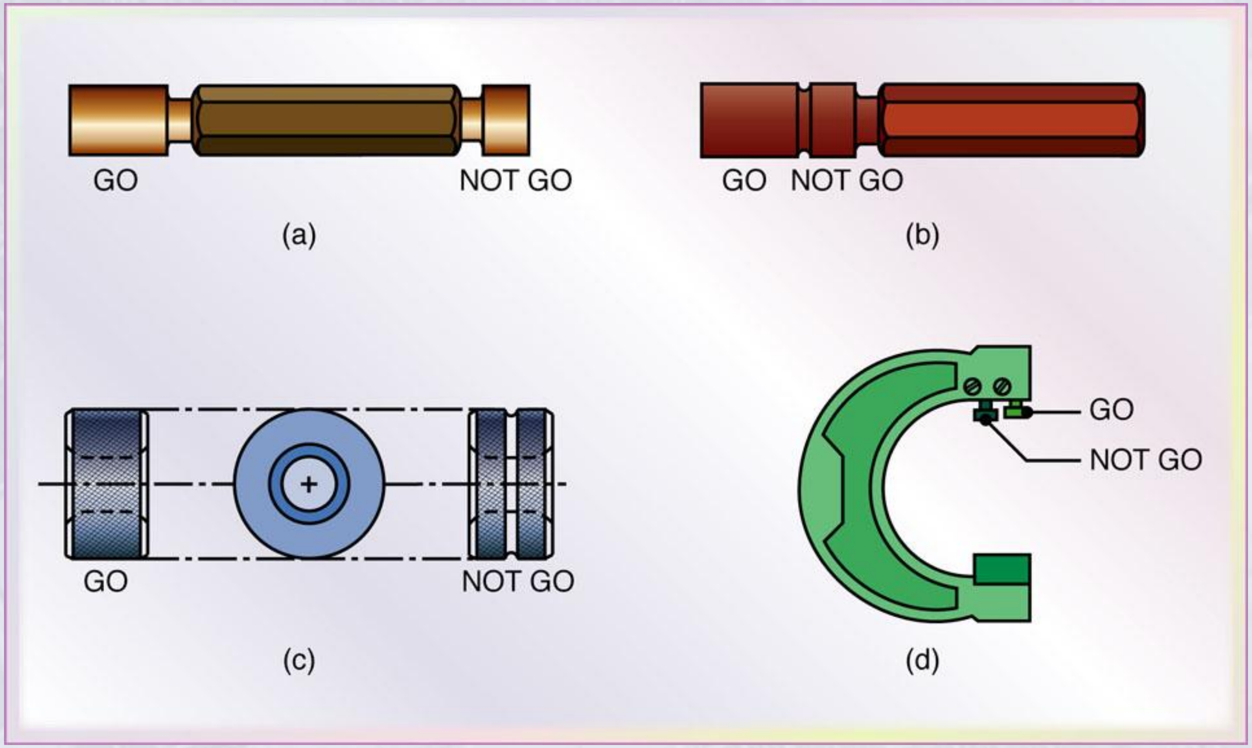
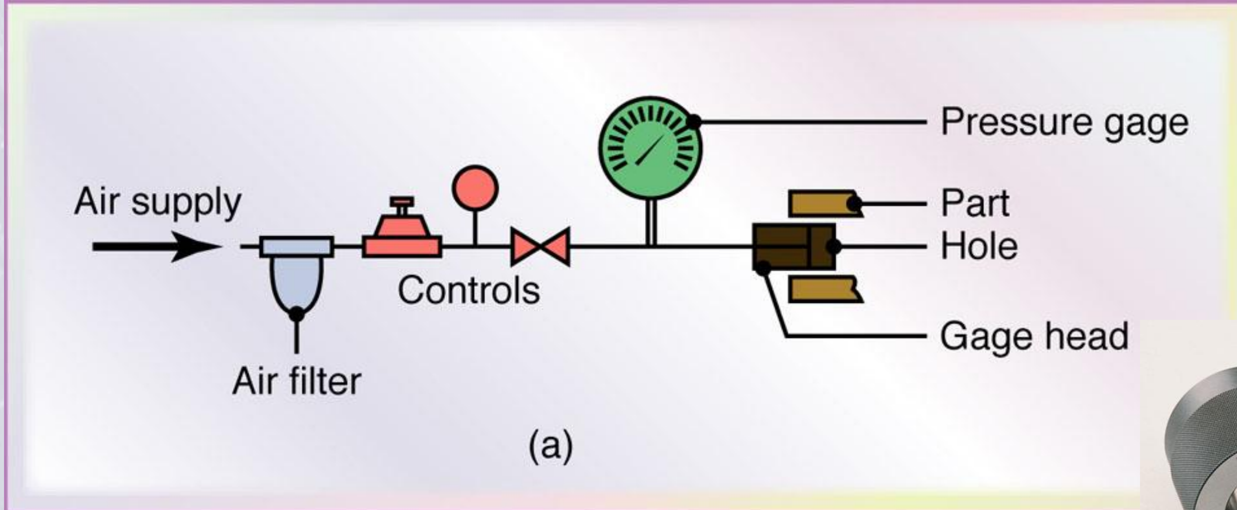
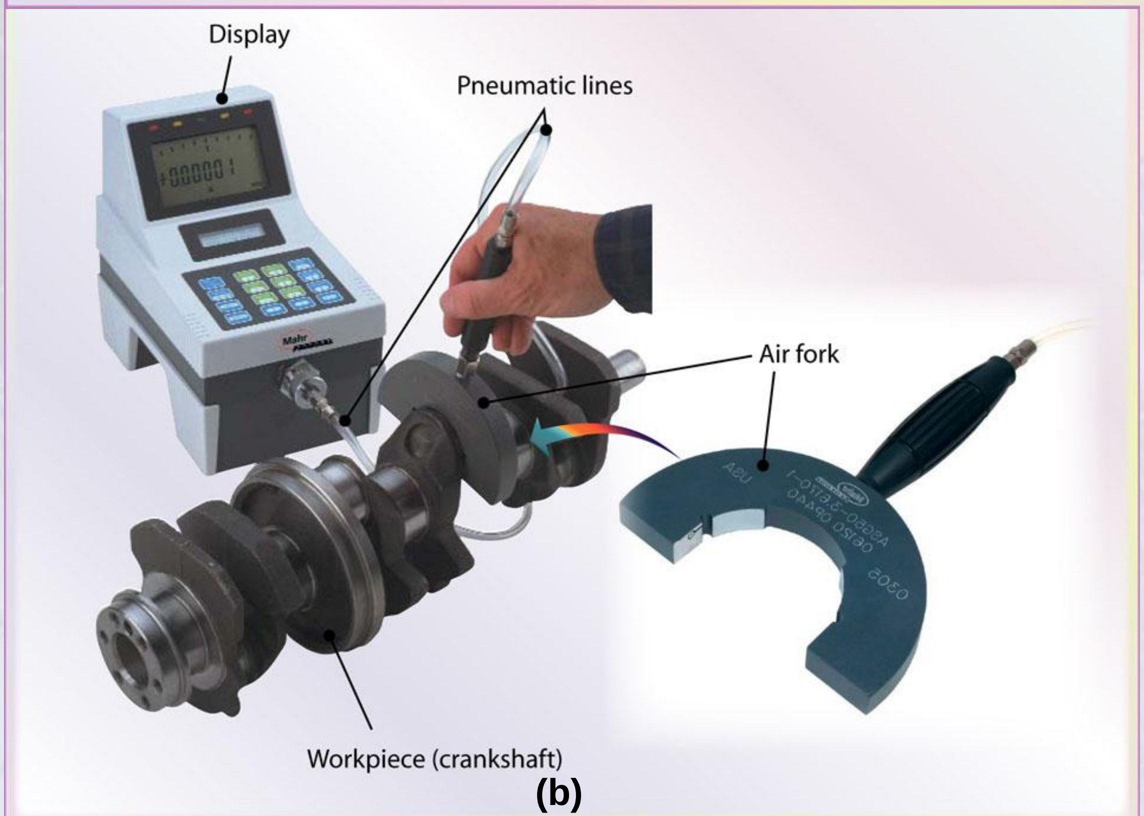


Figure 35.10 (a) Plug gage for holes with GO and NOT GO on opposite ends. (b) Plug gage with GO and NOT GO on one end. (c) Plain ring gages for gaging round rods. Note the difference in knurled surfaces to identify the two gages. (d) Snap gage with adjustable anvils.

Air Gages





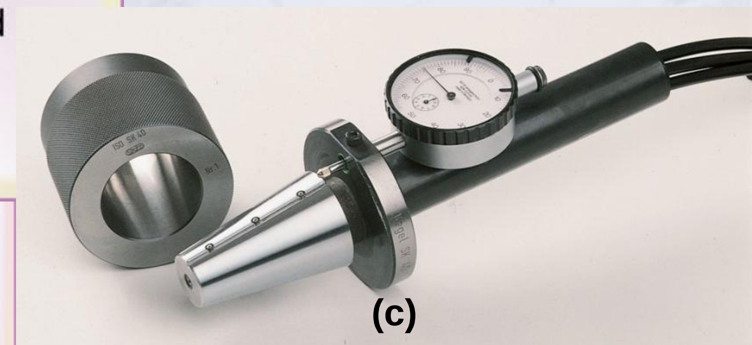


Figure 35.11 (a) Schematic illustration of the principle for an air gage. (b) Three types of plugs used for air gaging. The gage on the right is an air snap gage. (c) A conical head for air gaging; note the small air holes on the conical surface. *Source:* (b) Courtesy of Mahr Federal Inc. (c) Courtesy of Stotz Gaging Co.

Electronic Gage

Figure 35.12 An electronic gage for measuring bore diameter. The measuring head is equipped with three carbide-tipped steel pins for wear resistance. The LED display reads 29.158 mm. *Source*: Courtesy of TESA SA.

Electronic Gage Measuring Vertical Length

Figure 35.13 An electronic vertical-length measuring instrument with a resolution of 1 μm (40 μin). *Source*: Courtesy of TESA SA.

Laser Micrometers

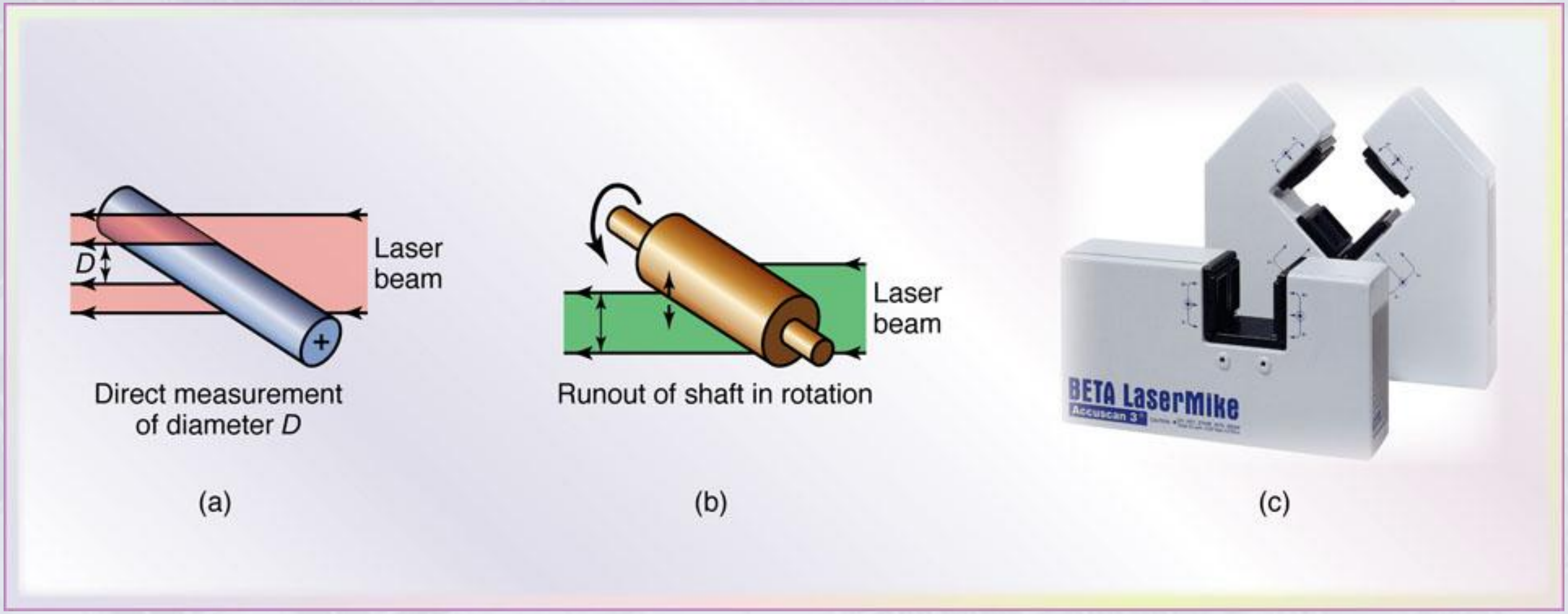


Figure 35.14 (a) and (b) Two types of measurements made with a laser scan micrometer. (c) Two types of laser micrometers. Note that the instrument in the front scans the part (placed in the opening) in one dimension; the larger instrument scans the part in two dimensions. *Source*: Courtesy of BETA LaserMike.

Coordinate-Measuring Machine

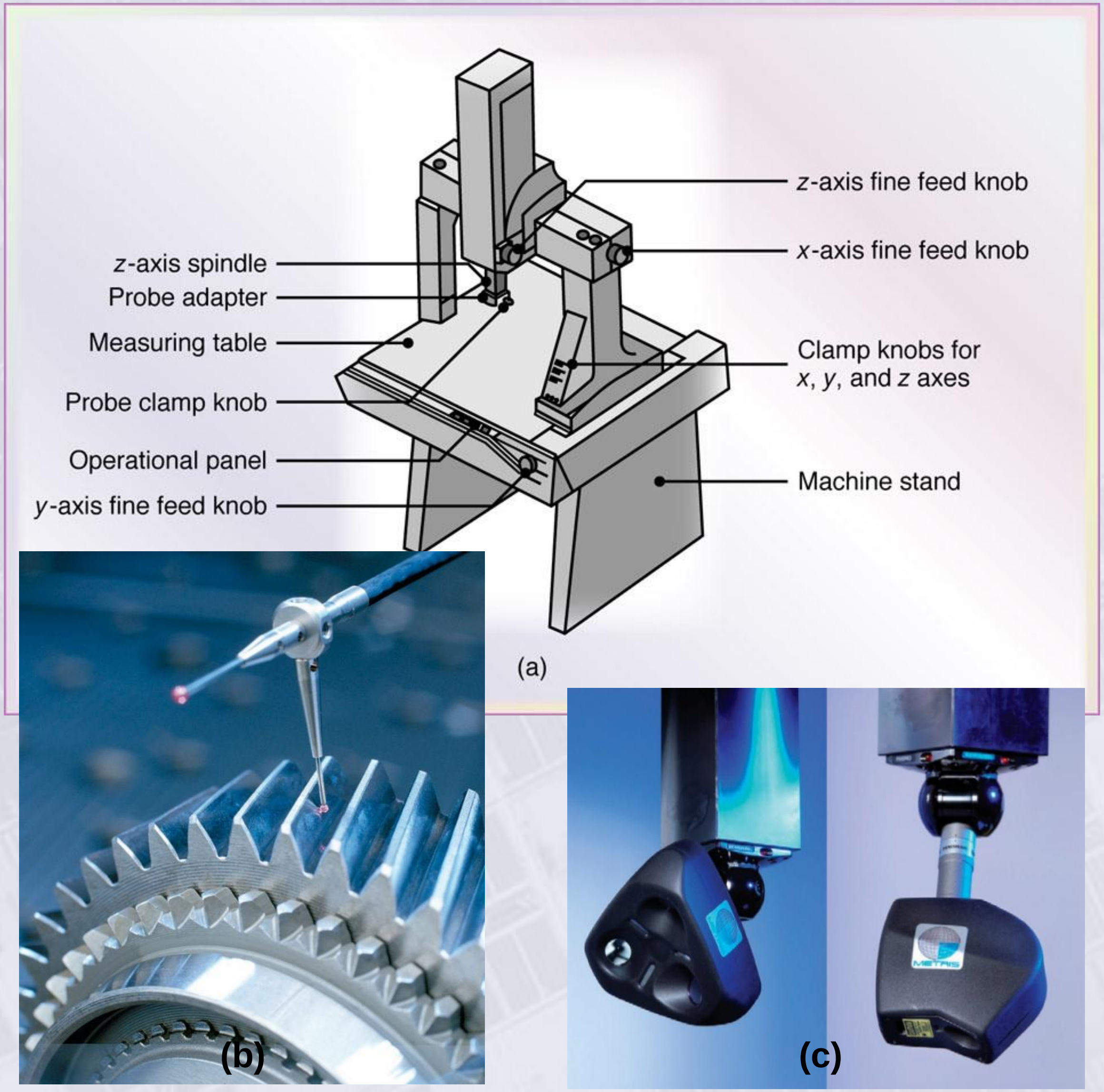


Figure 35.15 (a) Schematic illustration of a coordinate-measuring machine. (b) A touch signal probe. (c) Examples of laser probes. (d) A coordinate-measuring machine with a complex part being measured. *Source*: (b) through (d) Courtesy of Mitutoyo Corp.

Coordinate-Measuring Machine for Car Bodies

Figure 35.16 A large coordinate-measuring machine with two heads measuring various dimensions on a car body. *Source*: Courtesy of Mitutoyo Corp.

Tolerance Control

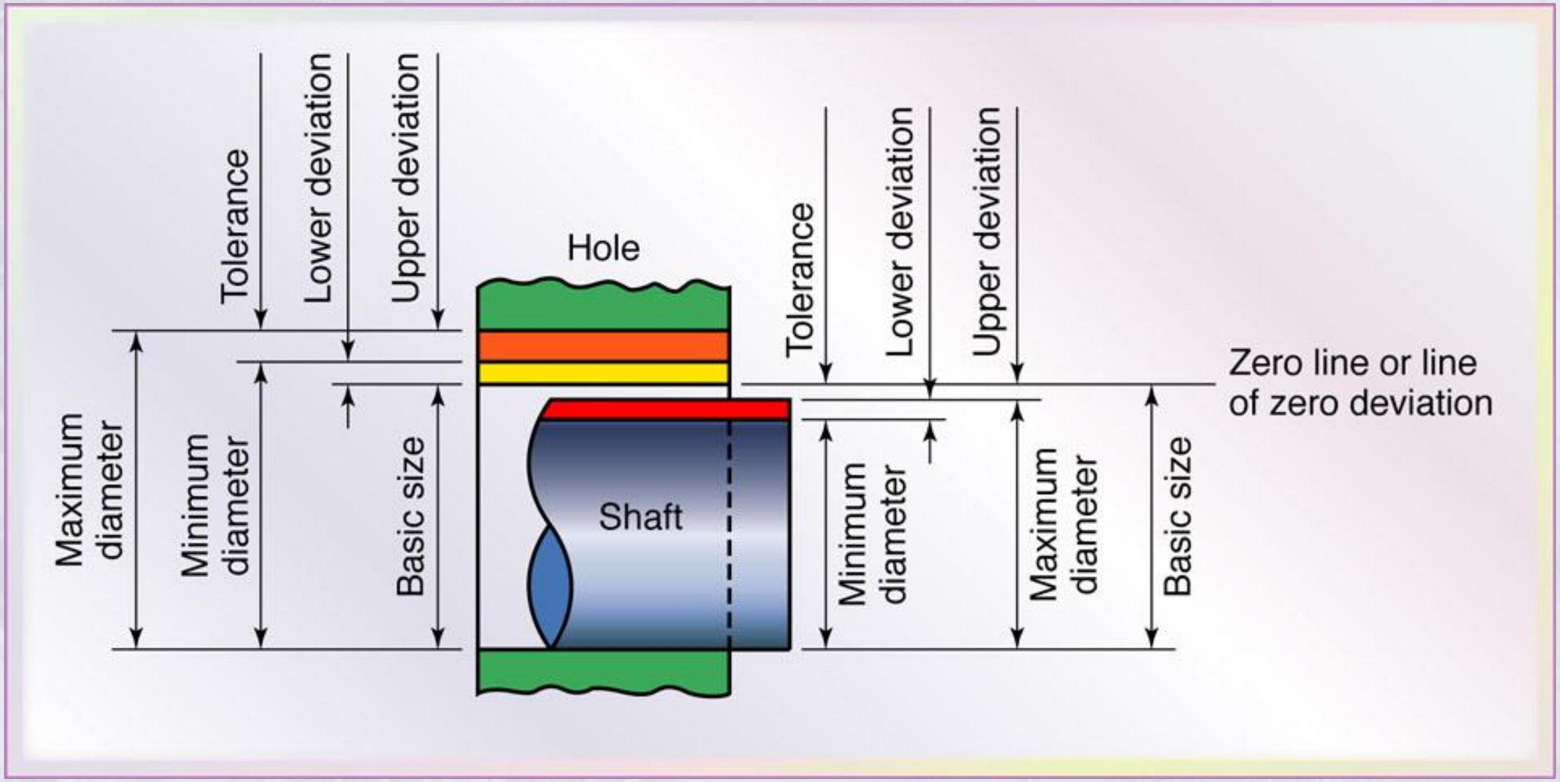


Figure 35.17 Basic size, deviation, and tolerance on a shaft, according to the ISO system.

Methods of Assigning Tolerances

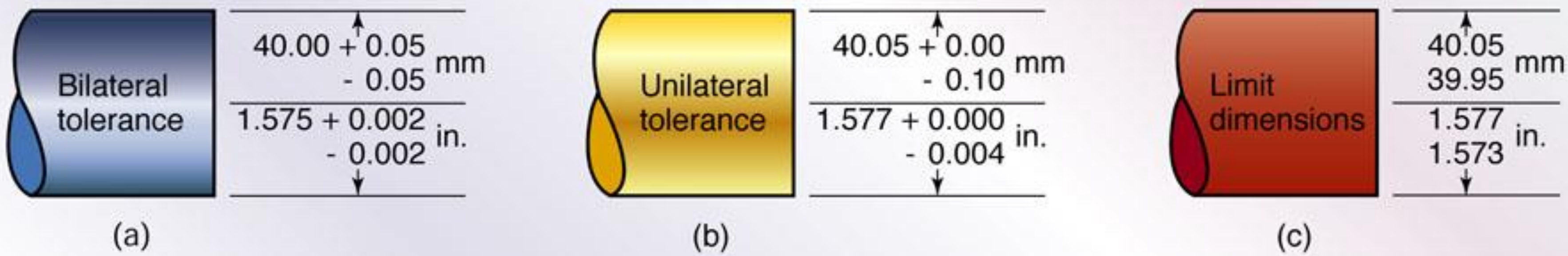
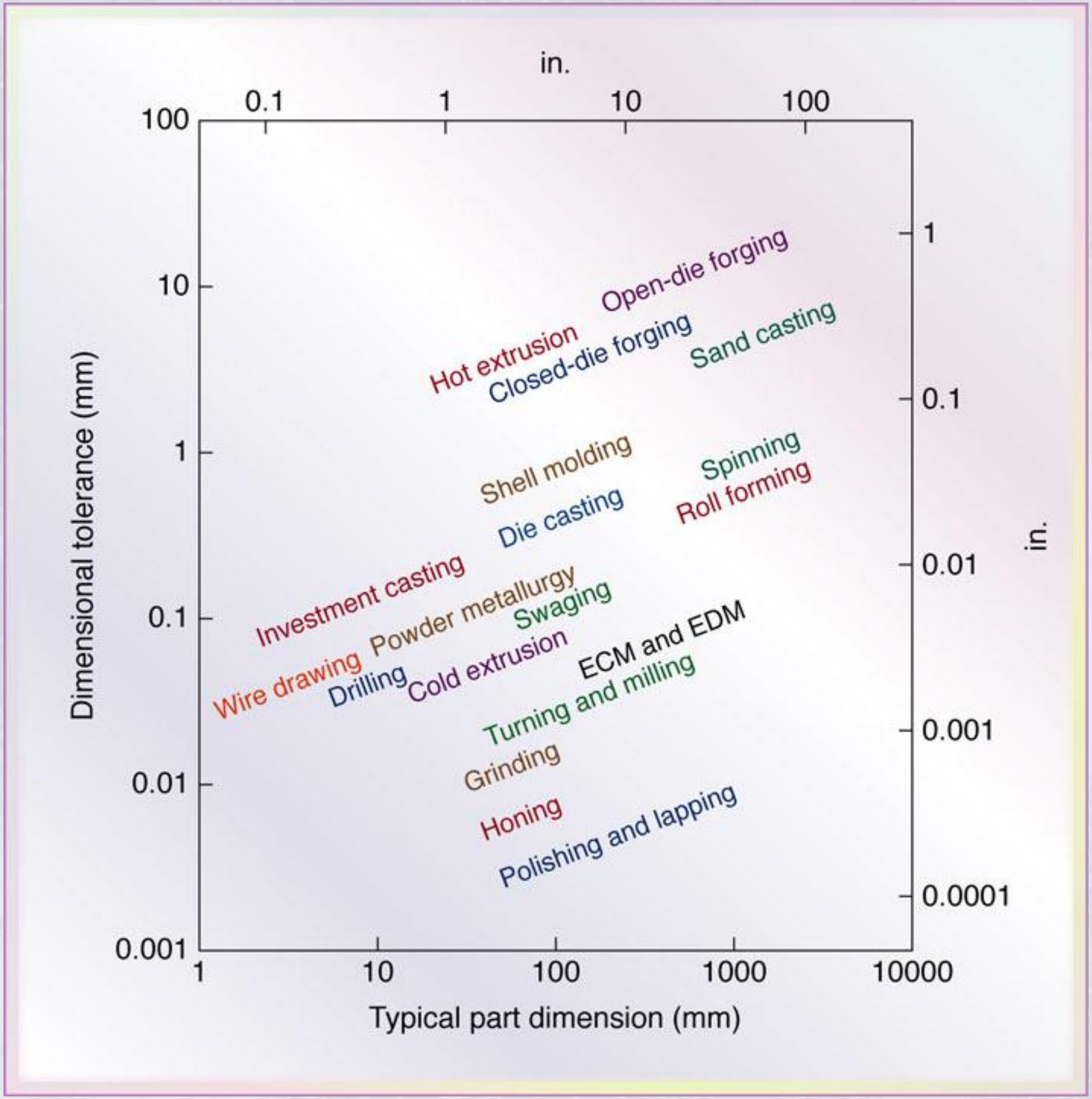
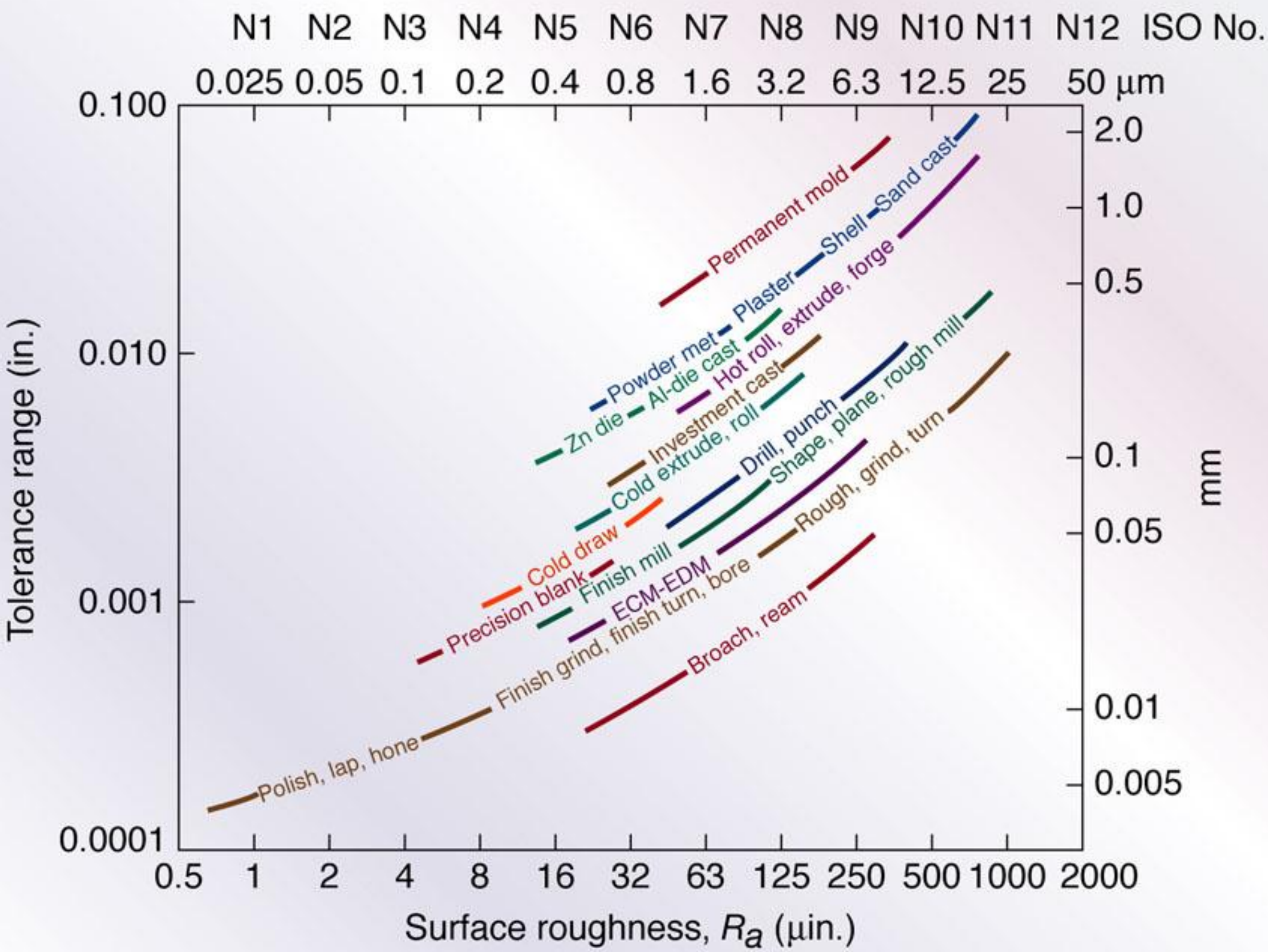


Figure 35.18 Various methods of assigning tolerances on a shaft:
(a) bilateral tolerance, (b) unilateral tolerance, and (c) limit dimensions.



Dimensional Tolerances as a Function of Part Size

Figure 35.19 Dimensional tolerances as a function of part size for various manufacturing processes. Note that because many factors are involved, there is a broad range for tolerances.



Dimensional Tolerance Range and Surface Roughness in Various Processes

Figure 35.20 Dimensional tolerance range and surface roughness obtained in various manufacturing processes. These tolerance apply to a 25-mm (1-in.) workpiece dimeinsion. *Source*: After J. A. Schey.

Engineering Drawing Symbols

Type of feature	Type of tolerance	Characteristic	Symbol
Individual (no datum reference)	Form	Flatness	⏥
		Straightness	—
		Circularity (roundness)	○
		Cylindricity	⌭
Individual or related	Profile	Profile of a line	⌒
		Profile of a surface	⌓
Related (datum reference required)	Orientation	Perpendicularity	⊥
		Angularity	∠
		Parallelism	//
	Location	Position	⌖
		Concentricity	◎
	Runout	Circular runout	↗
		Total runout	⌰

(a)

- [.605] Basic or exact dimension
- [-A-] Datum feature symbol
- Ⓜ Maximum material condition
- Ⓢ Regardless of feature size
- Ⓛ Least material condition
- Ⓟ Projected tolerance zone
- Ø Diametrical (cylindrical) tolerance zone or feature
- [⌖ | Ø.005 Ⓜ | A] Feature control frame
- (A1) Datum target symbol

(b)

Figure 35.21 Geometric characteristic symbols to be indicated on engineering drawings of parts to be manufactured. *Source*: Courtesy of The American Society of Mechanical Engineers.